Comparison of some simulated and actual CDA trajectories

Plus comments on validity and prediction accuracy

Goal

- Build a simulation capability for CDA descents of commercial aircraft (TOD to TRACON entry)
- Determine accuracy of CDA descent predictions to determine reasonable spacing & delay requirements for time-based scheduling for high density CDA/non-CDA traffic
  - Determine delayability requirements to achieve required spacing at entry to TRACON

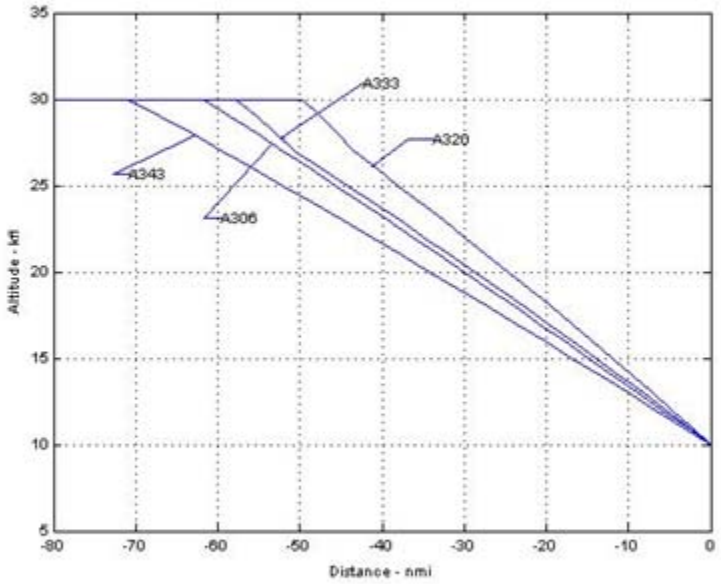
Simulations

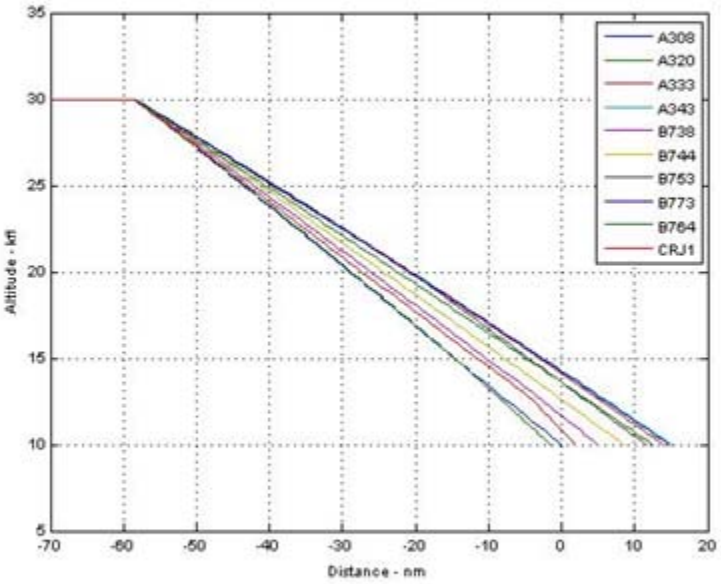
- Matlab code developed to fly constant CAS/Mach descent trajectories
  - Concentrate on idle thrust descent trajectory from TOD to Meter fix altitude
  - Trajectory options: a) constant CAS/Mach; b) constant FPA; c) constant CAS & FPA (variable thrust/drag)
- Use BADA database of aircraft information to generate trajectories
- Simulation allows for variable winds, non-standard temperature, as well as choice of weight, descent CAS/Mach
- I choose to end my simulations at 11kft to omit consideration of decel segments
- The goal is to determine the accuracy with which we can compute CDA descent times- important for scheduling

BADA data- comments

- Data defines “nominal” aircraft aerodynamics, weight, thrust, speeds
- Some aero data seems very inconsistent.
  - E.g. L/D)max = 15.4 (757-300); 19.1 (767-200);17.7 (767-400). What is correct? (Changes descent time by 3 minutes) (Note: Airbus data similarly inconsistent!)
- “Nominal” cruise aero lacks Mach dependency- probably important for high speed descent
- Reference descent speeds too slow (typ 280->340)
- Idle thrust is small but some data has discontinuities

Some sample simulation runs





Comments on simulations

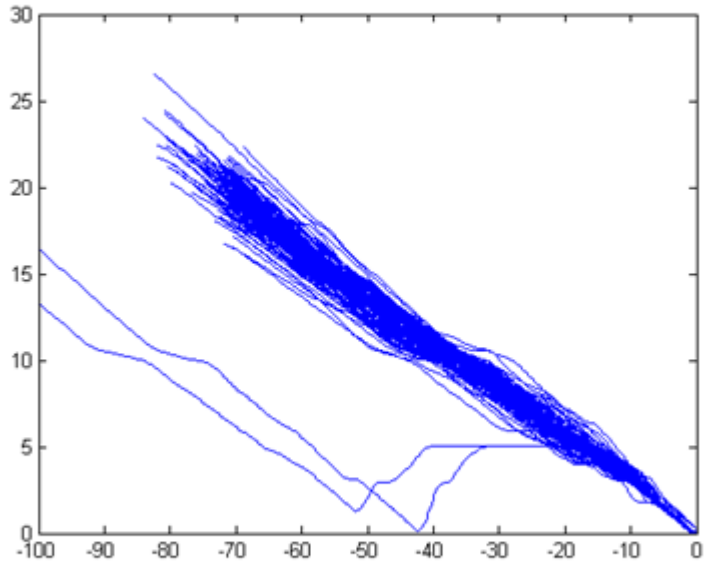
- BADA data sets available for most aircraft – but not all engine combinations
- Nominal “cruise” aerodynamics used for descents. No mach dependency
- Nominal speeds available (cruise; descent;..) but actual data is quite different
- Use “descent” thrust
- Constant winds affect descent distance- but not time
- Altitude variation in winds affects both time and distance
- Descent very sensitive to assumed aerodynamic model and descent speed
- Less sensitive to weight

Descent data

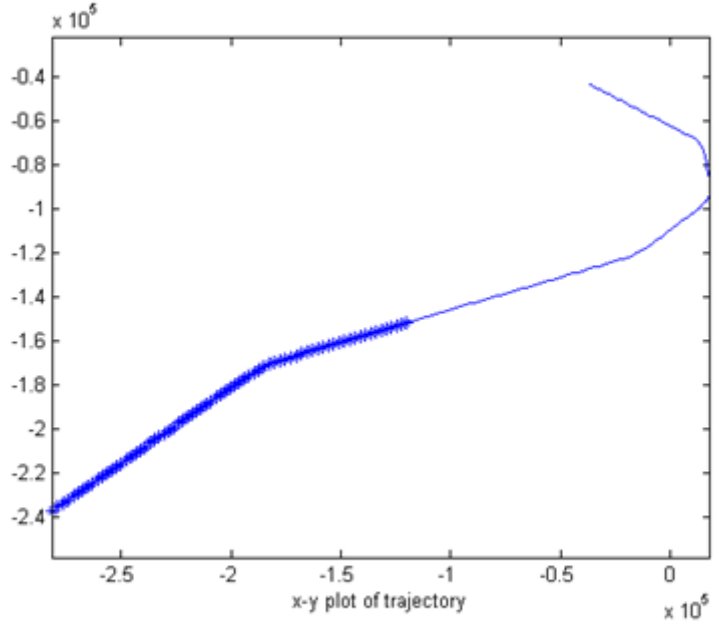
- Tailored arrivals SFO
  - B777, B747
  - X,y,z,Vg data. No wind, weight
  - Initial altitude 17-25 kft
- CDA at SDF
  - DFDR data
  - Data from before TOD to runway

SFO 747 TA

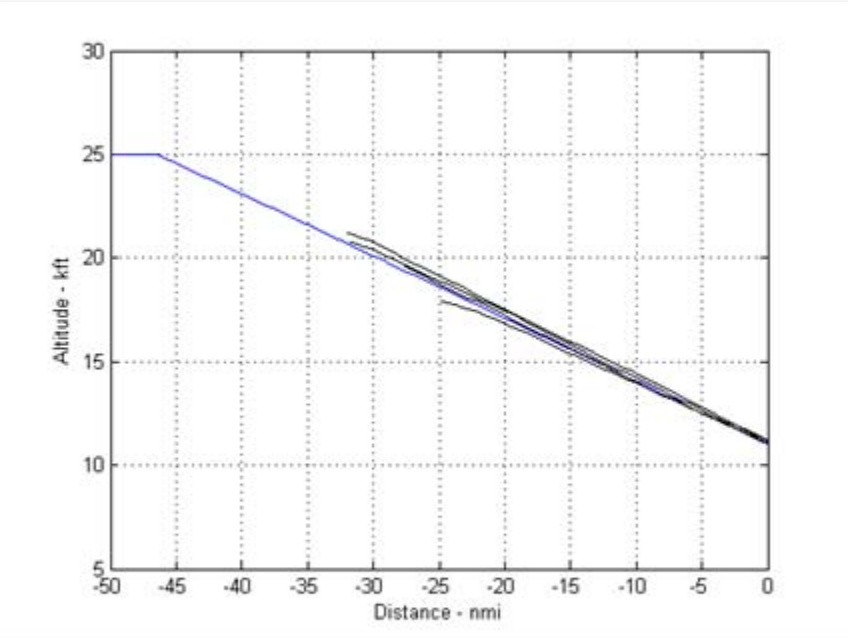
Descent profile (all ac)



Typical ground track



Sample SFO results



- Short data range makes comparisons difficult
- Lack of weight detracts from comparisons
- Choose selected flights with relative smooth CAS descent
- Assume Vground = TAS. Data shows significant CAS variation during descent for most aircraft

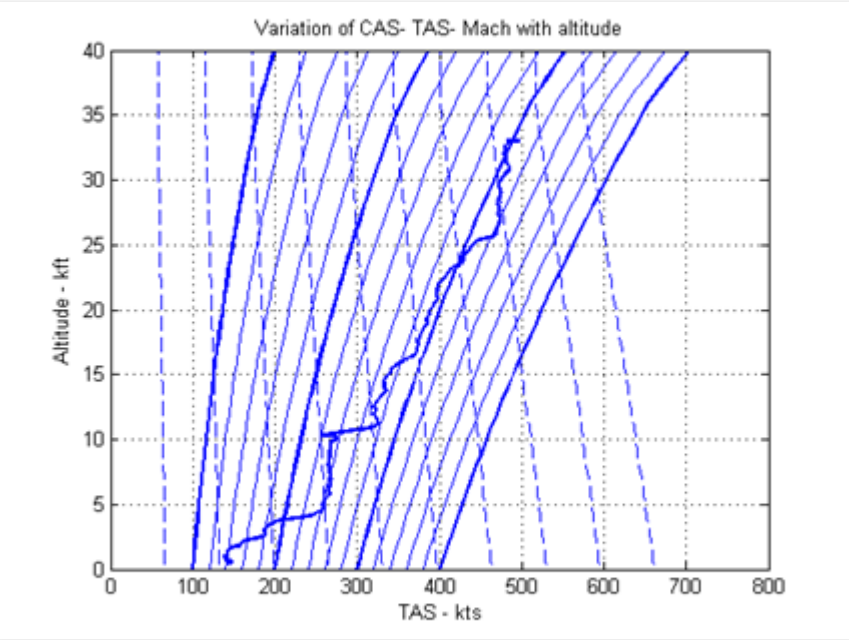
B747 data (SFO) 280kt descent

SDF data

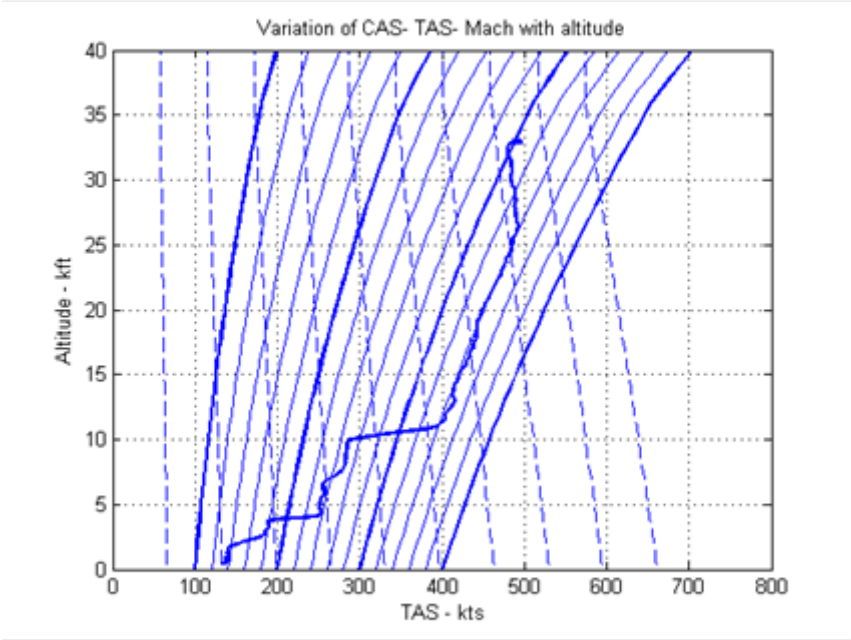
- Two weeks data: B757, B767 ac
- DFDR has CAS, Vg, Wind info in addition to x,y,z, …
- Data goes from before TOD to runway (typically 35-40kft)
- To compare data to sim, truncate DFDR data at 11kft

CAS/mach variation often not smooth see CAS- example 767 data

Variable CAS/Mach



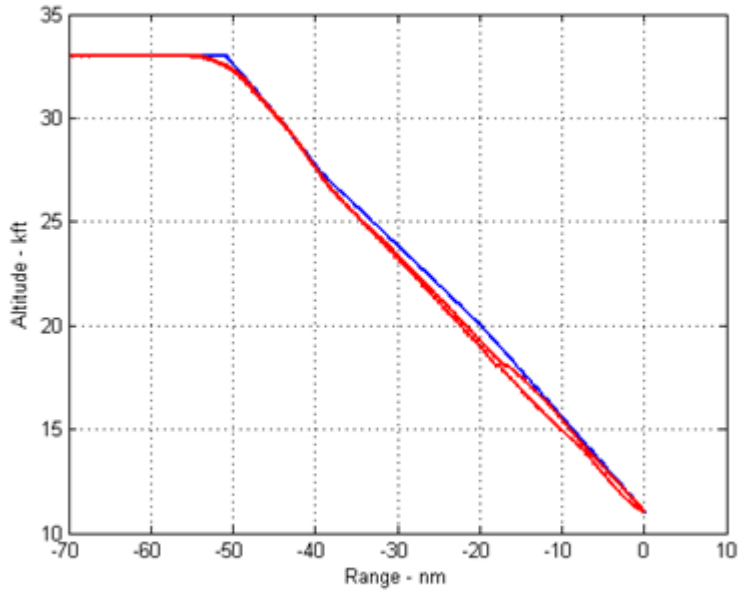
340/.82 descent



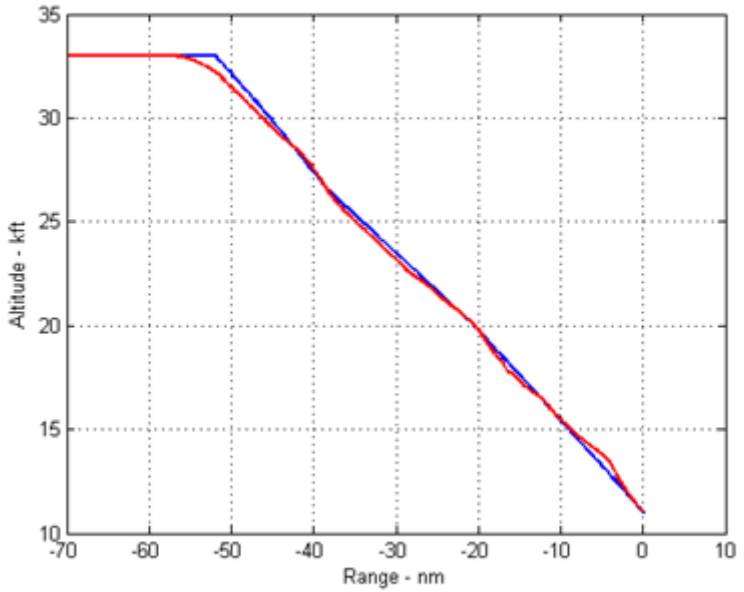
Note: Convert CAS to TAS/Mach using standard atmos model

SDF 757 data

757 (162klb)



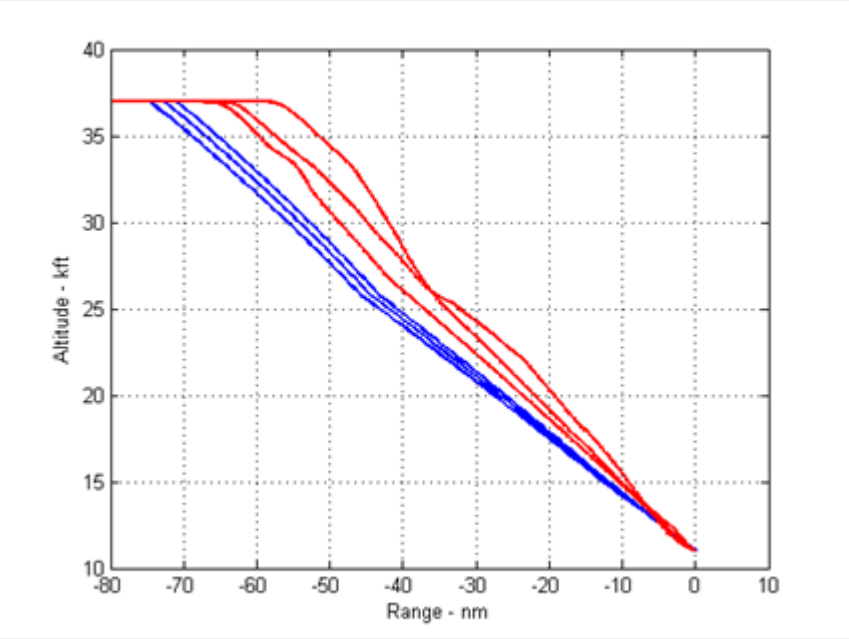
757 (180klb)



Some of the data fits very well- Best case times here accurate to a few seconds!

767-200 data; W= 250-270klb

Typical descent 340/.82

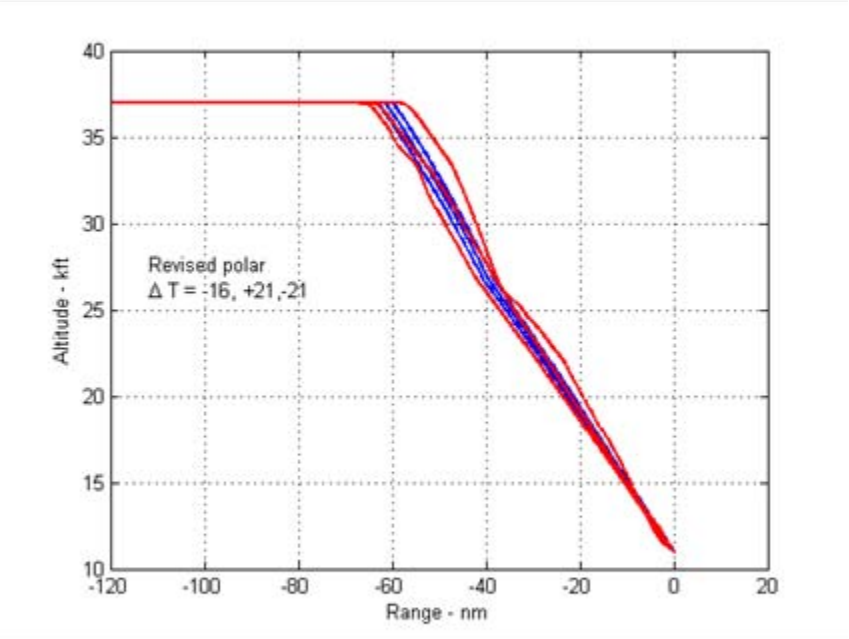


Using original BADA data

- 767-200 drag too low
  - (L/Dmax=19.1!)
- Distance error ≈10-15nm
- Time error ≈ 60-90 sec

Switch to BADA 767-400 polar

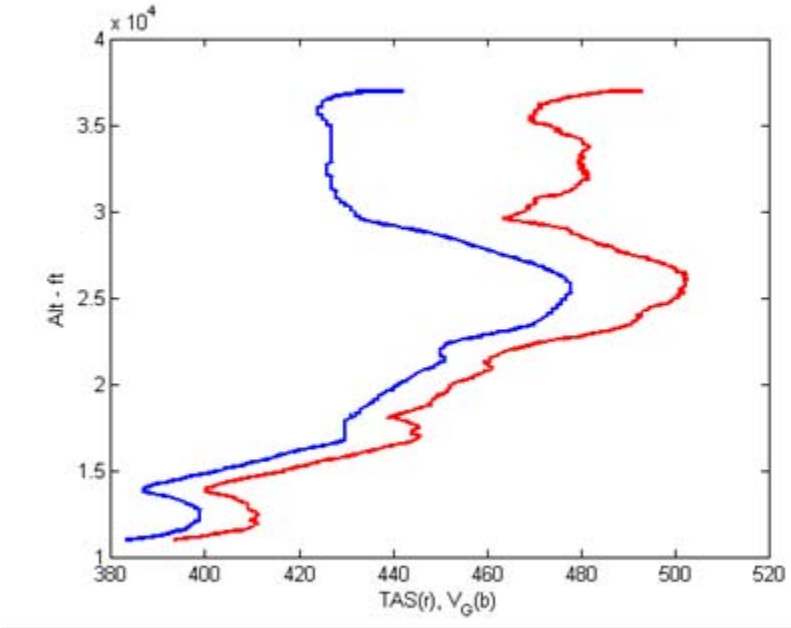
Repeat 767-200 w/modified drag

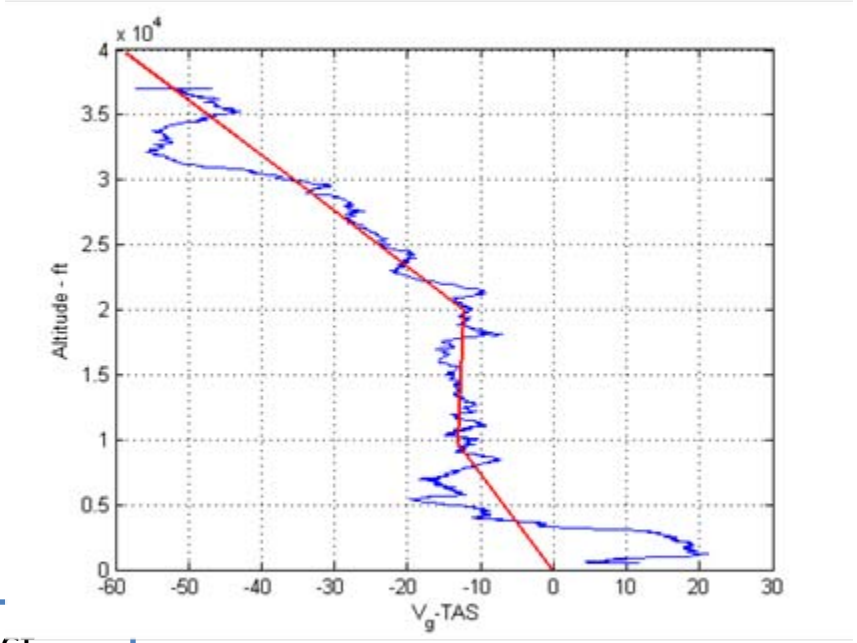


- Use BADA drag model for 767-400
  - CDp=.014->.0173
  - L/Dmax= 19.1 ->17.7
- Distances from TOD much improved
- Time error (from TOD) ±20sec

Winds aloft?

Winds can affect the data. See sample data below. Try to resolve wind information to improve descent calculations





R- TAS (from CAS); B- VG(data); Expect winds to be a significant parameter

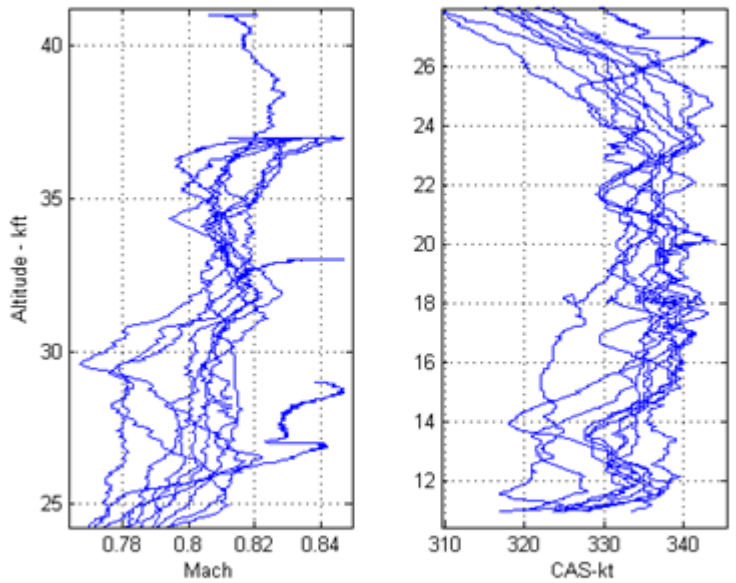
We model winds using piecewise linear model. Effect of winds seems to be minimized by FMS?

DFDR flight data

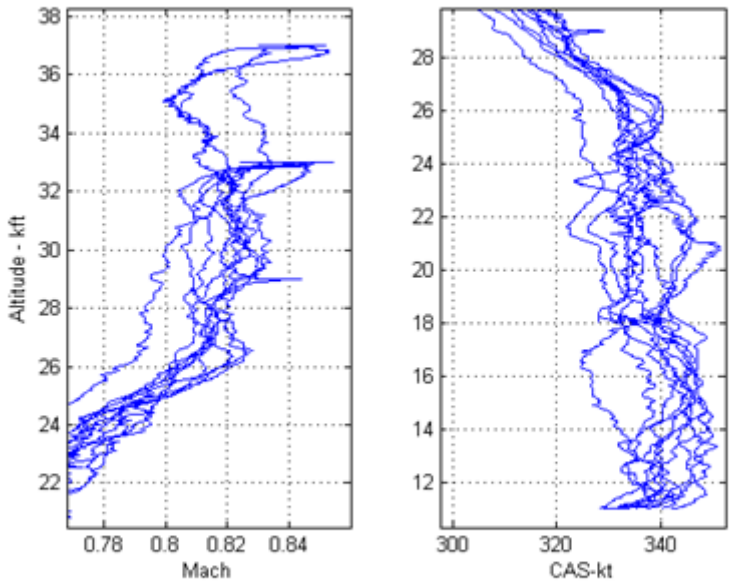
- We assume constant CAS/Mach is aim– Actual FMS operation seems quite different
- Actual CAS/Mach on descent can be very erratic
  - Only a few descents have a consistent smooth speed variation! Makes accurate prediction very difficult.

Observed descent speeds

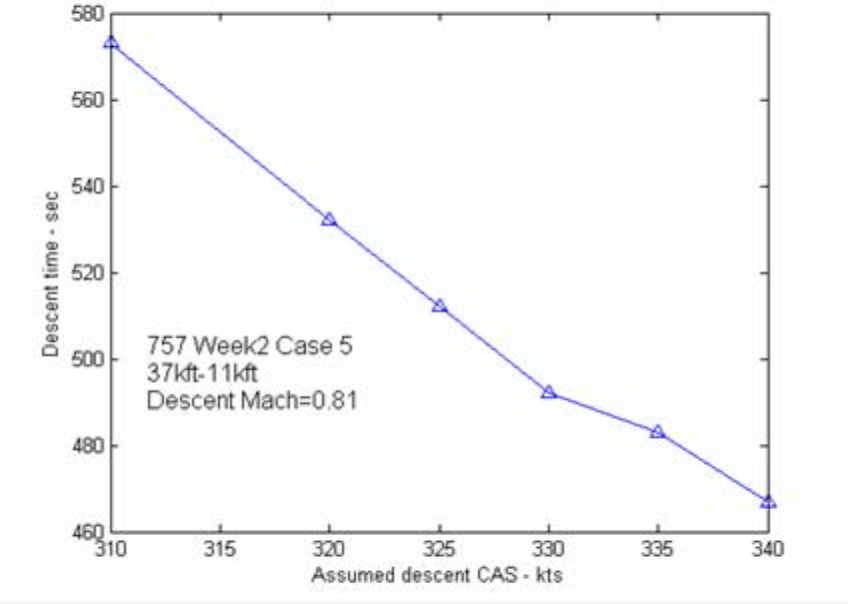
757



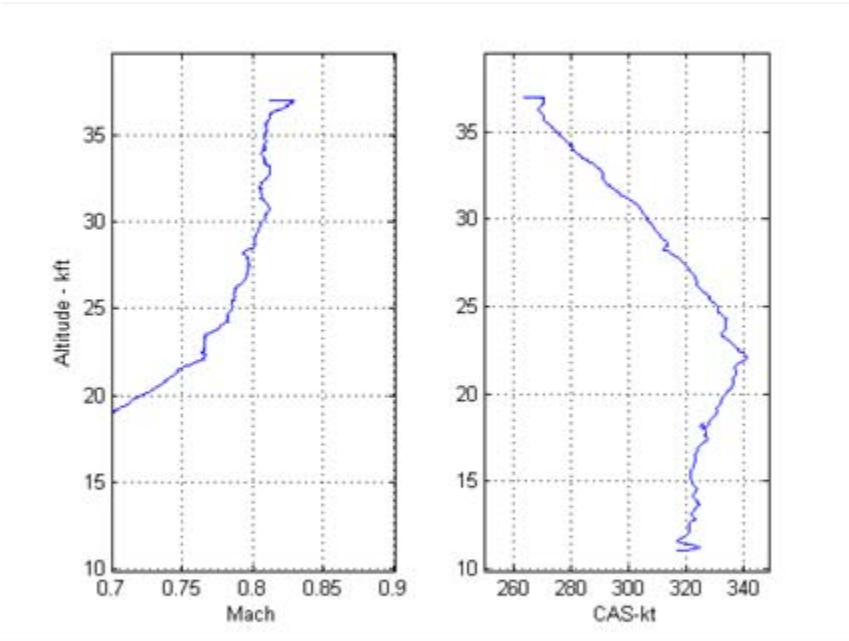
767



For any particular ac it can be difficult to pick a descent mach/speed profile- Strong effect on descent calculations



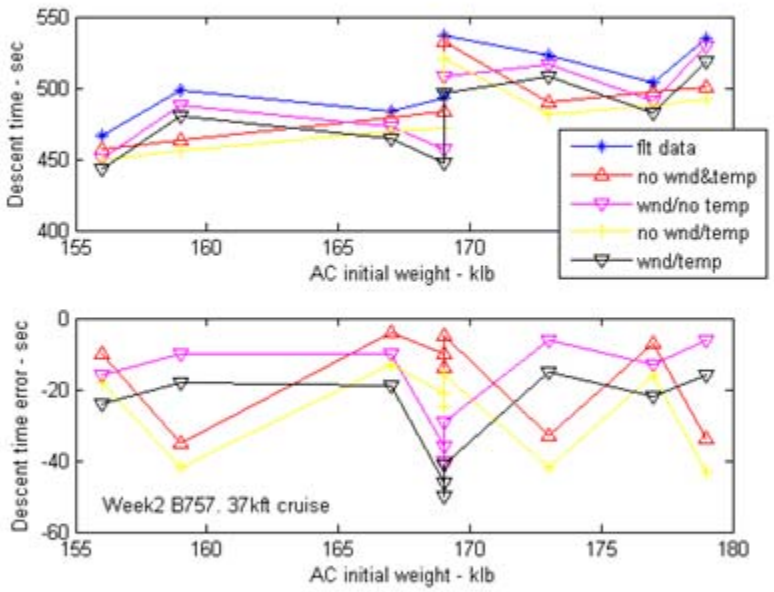
Calculated decent time for different assumed descent speeds. (Actual time – 537 sec)



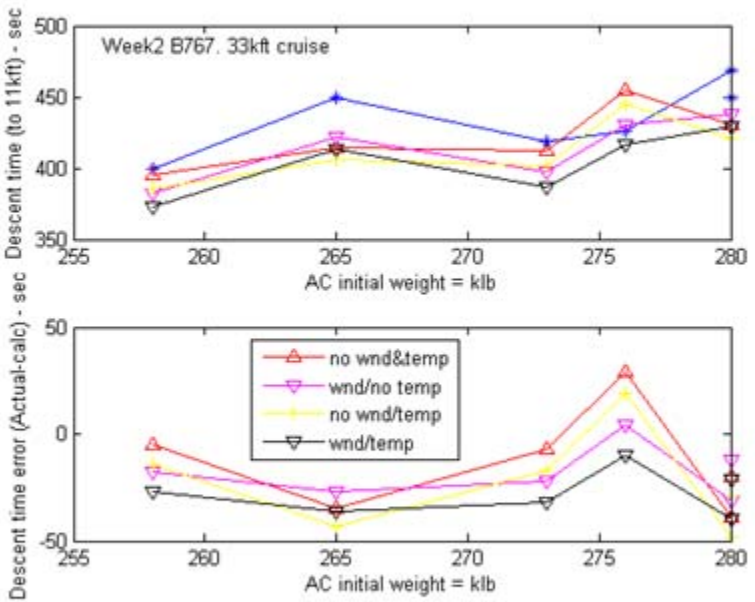
Recorded CAS-Mach descent profile for one case

Weight and descent speeds major factors in descent time. Winds and non-standard temperature are not

SDF - 757 Week 2

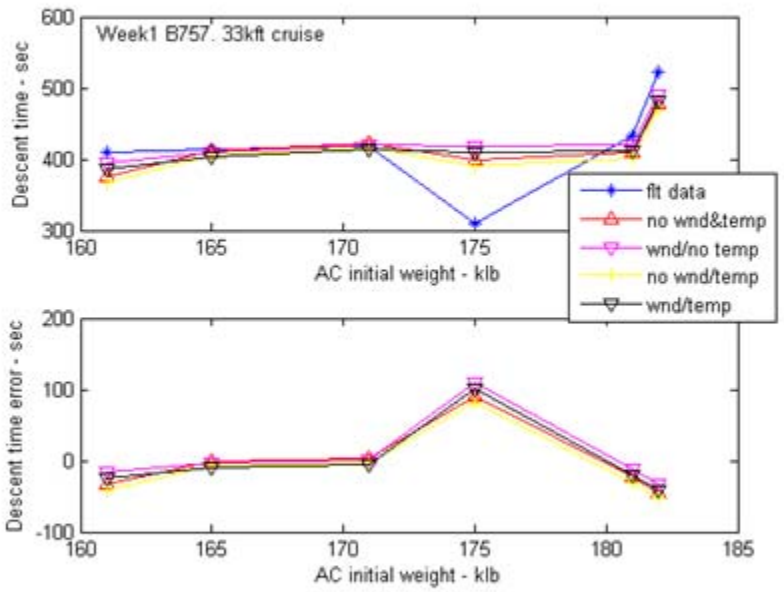


Week2 767

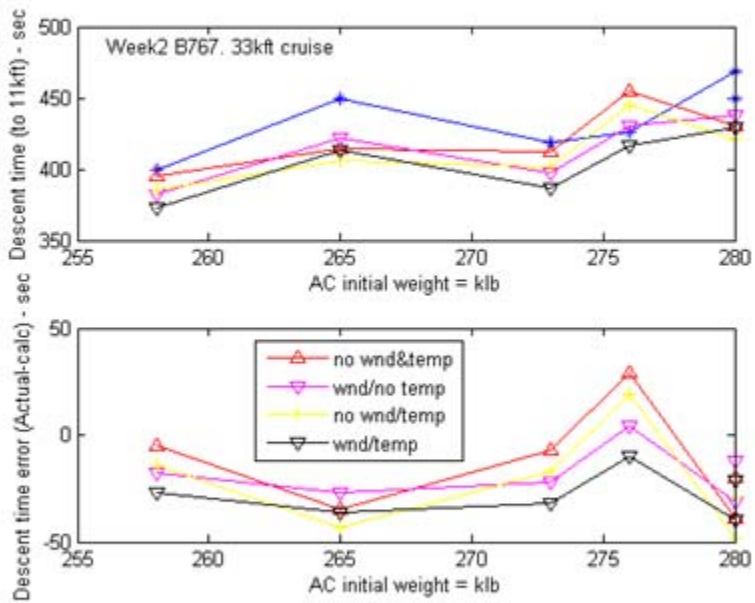


Assumed CAS/M for descent calculations vary based on observed data (typ 320-335 kts)

Week1 757



Week1 767



Overall statistics (36 ac)

- Choose “best” speed & weight
  - Average error = -19sec (Max error ≈100sec)
- Add wind estimate (post priori data)
  - Average error -13 sec (Max error ≈100sec)
- Add temperature data
  - Average error -32 sec

Summary

- BADA database OK for general studies- but need more accurate data for realistic scheduling
- Need more data to determine if UPS descent data is representative of “normal” commercial traffic (based on SFO data– NO)
- Based on UPS results, typical accuracy of descent prediction is on the order of 30sec. (note errors typically < 0 --with a few very bad cases) Better aero model might help remove bias.

Summary (2)

- For most flights, it was difficult to choose a "constant CAS/Mach" descent. Adding wind info helped time predictions slightly. Temperature data did not help
  - Related to FMS control algorithm?
- Descent distances are also important- but were not part of this analysis. (Typical errors in distance: 3-7 nm)
- More data?

Questions?

A distance error plot- 757